Emergent states of matter in chemically doped quantum magnets

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Impurities in materials are not always unwanted. In fact, they can play a central role in scientific and technological breakthroughs. This study provides crucial insights into impurity effects in the two-dimensional Shastry-Sutherland quantum magnet, $SrCu_2(BO_3)_2$

Substituting small amounts of Mg for Cu (called "chemical doping") in $SrCu_2(BO_3)_2$ crystals creates emergent magnetic states where the Mg impurities couple with spin triplet bound states. This results in localized bound states at two threshold magnetic fields (H_{c3} & H_{c2} in the Fig.a) and paired impurity states at H_{c1} and H_{c0}. *The experimental and numerical results are in remarkable agreement, confirming our discovery of a rare example where even a small doping concentration significantly alters the ground state of a frustrated quantum magnet, leading to stable impurity pairs and inducing new spin states at high magnetic fields.*

Understanding the impurity effects in the doped $SrCu_2(BO_3)_2$ system opens the door to realizing long-sought-after quantum materials such as resonating valence bond (RVB) superconductors. This work may also shed light on quantum phase transition paradigms that go beyond the conventional Landau-Ginzburg-Wilson theory.

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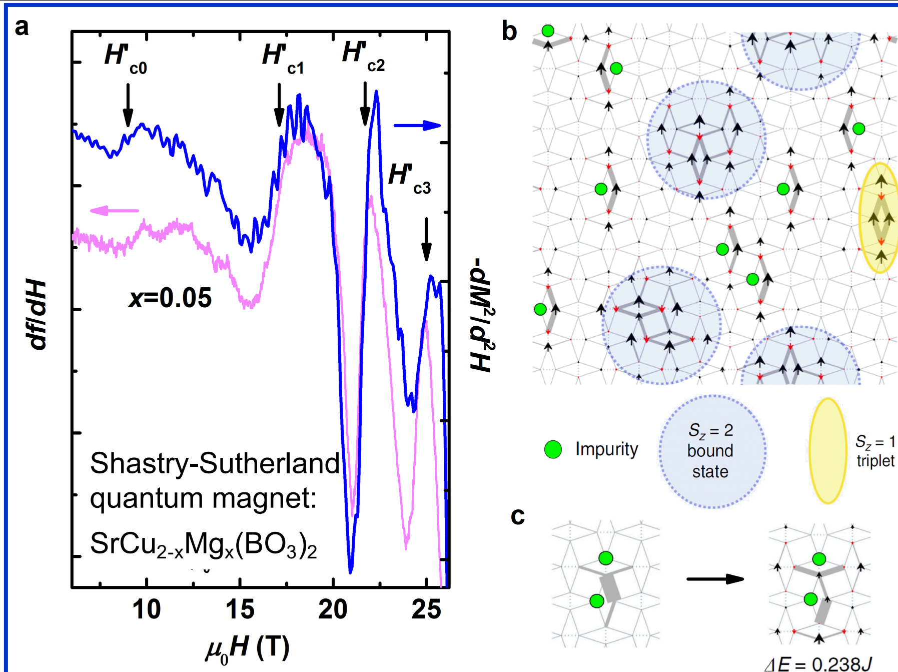

Figure (a) Emergence of magnetization anomalies, indicated by the black arrows, are shown in Tunnel Diode Oscillator data, df/dH (magenta, left axis) and magnetization, $-dM^2/d^2H$ (blue, right axis) versus magnetic field. (b) Spin configuration above H'_{c3}, obtained in the total $S_z = 11$ sector. The size of the spins scale with the magnitude of the local magnetic moment, where black (red) arrows point along (opposite to) the external magnetic field. The thickness of the gray bonds scales with the local bond energy (the thicker the lower the energy). (c) Special 2-impurity configuration in the $S_z = 0$ (left) and $S_z = 1$ (right) sectors, respectively, with an excitation energy $\Delta E = 0.238J$.